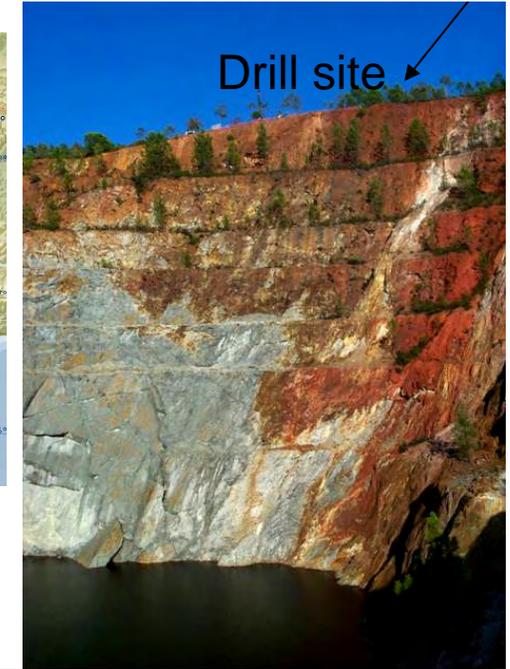
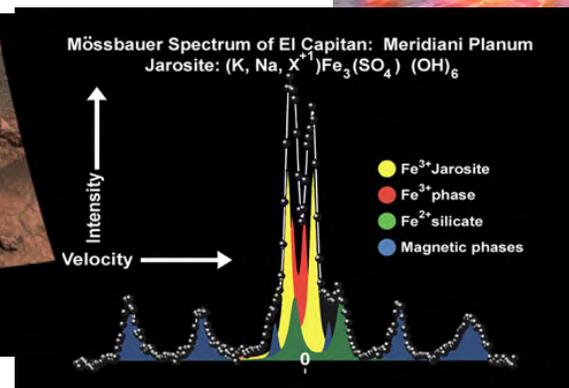
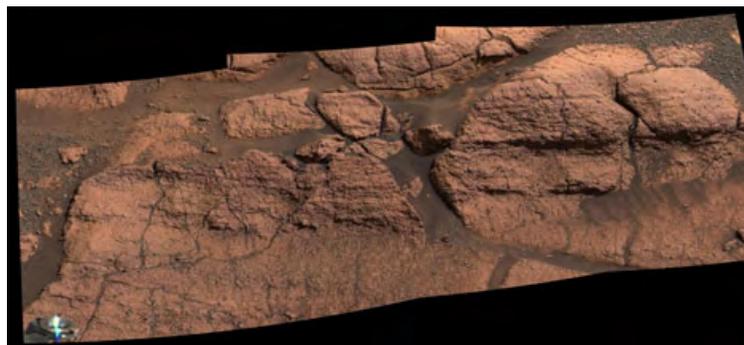


Overview

- The Mars Astrobiology Research and Technology Experiment (MARTE) performed a (simulated) Mars drilling mission to search for life.
- • “Landing site “ for mission was at source of Rio Tinto, Spain, a possible modern analog to conditions on Mars that formed Jarosite rich deposits at Sinus Meridioni.



pH 2.3 river, iron sulfates form



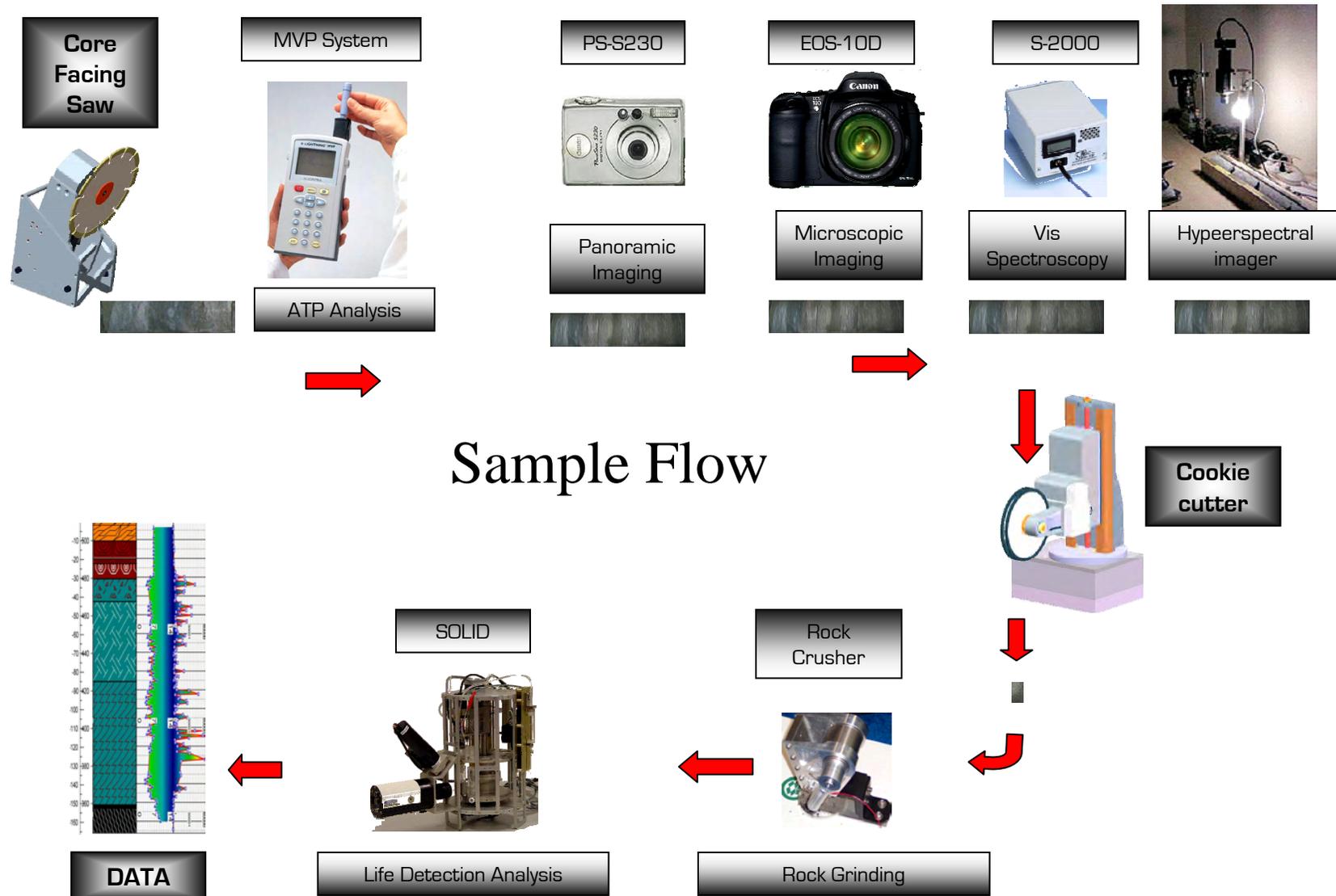


MARTE Drill Platform

- Drill and core retrieval system built by Honeybee Robotics.
- 10 m depth capability
- Power consumption 150 watts
- Each core bite is 25 cm long, 2.7 cm diameter
- Dry rotary cutting using carbide drag cutters and diamond bits
- Core hand off to a core clamp
- Automated drilling, core removal, and string replacement

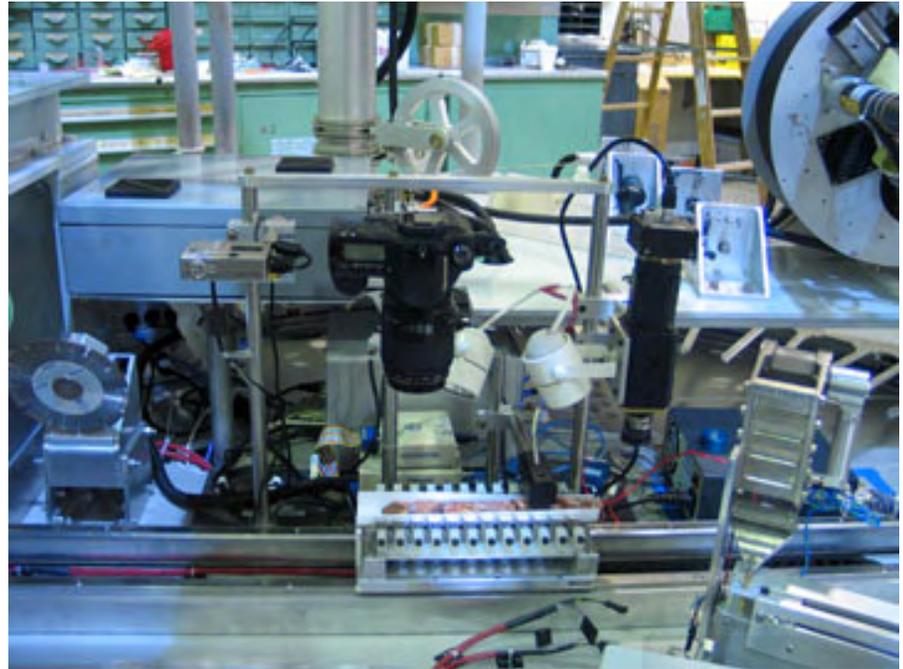


Robotic Sample Analysis

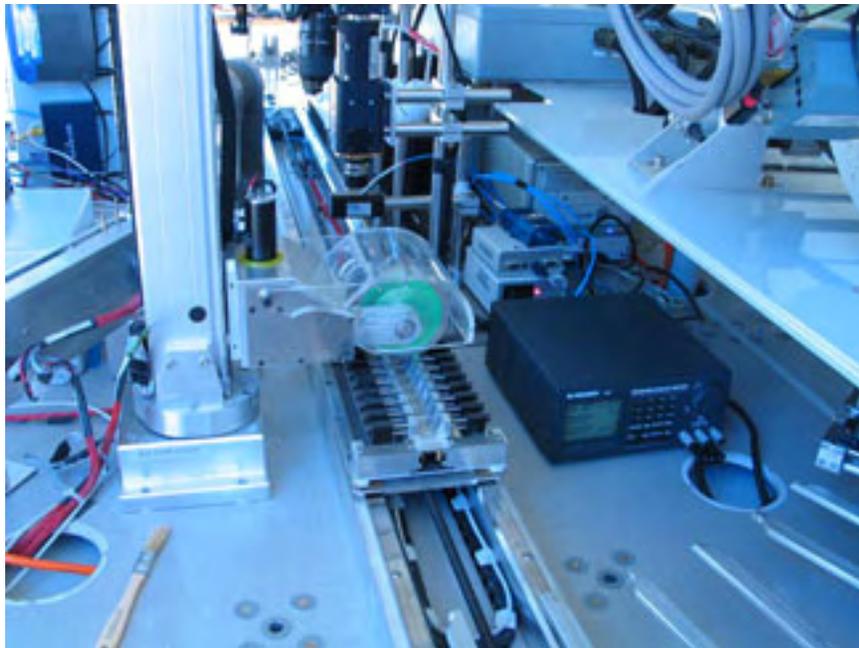




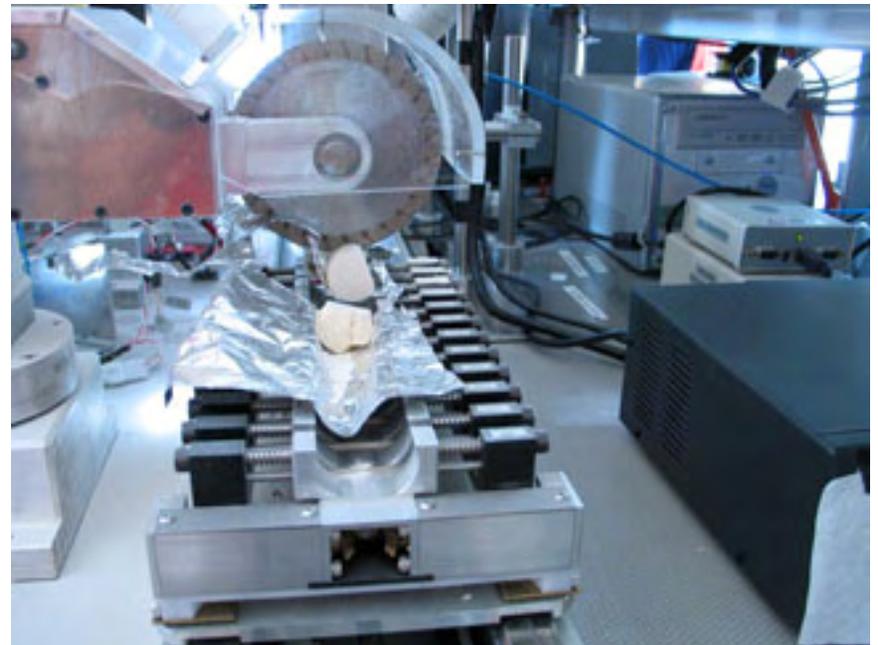
Faced core goes under Remote Sensing instrument package



RS instruments examining core



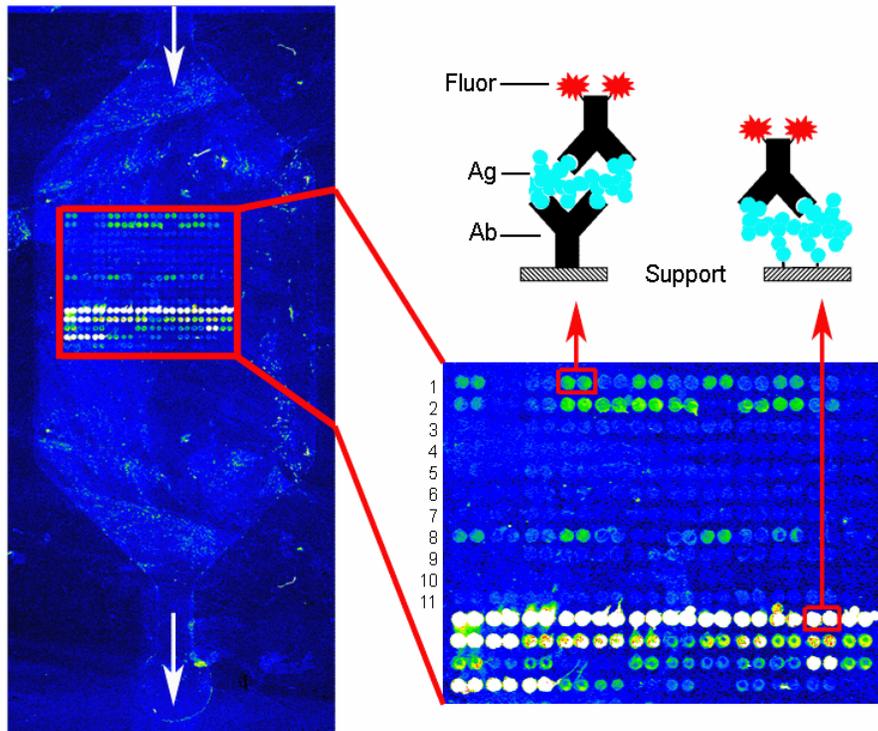
Subsample saw



Sample acquired

Life Detection Instrument

- Uses Protein microarray technology to detect microorganisms and their metabolic byproducts
 - Uses microarrays printed with antibodies able to recognize and bind specifically to them.
 - Arrays contain probes to detect organic compounds and whole cell characteristics from the powdered core samples
 - Product of SOLID analysis is an image showing where an antibody was detected.



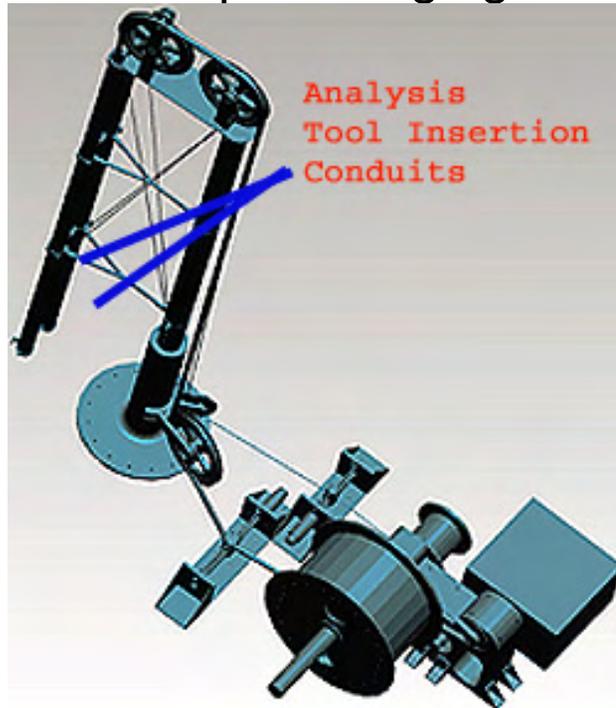
SOLID (Signs of Life Detector)



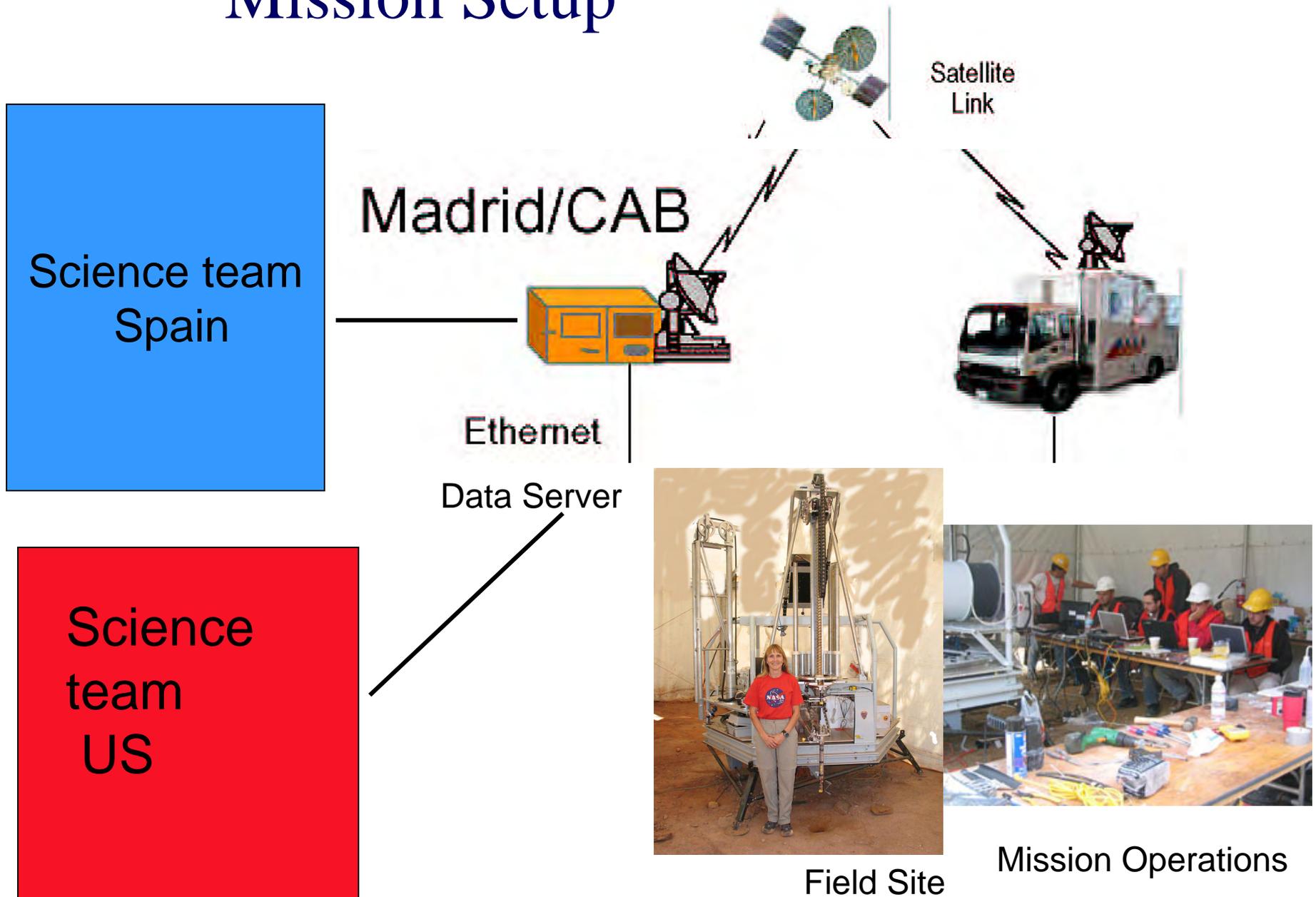
From CAB Madrid

Down Hole Instrumentation

- The Bore Hole Inspection System inspects hole after removal of the drill
- Instruments in the BHIS include a panoramic microscopic imager and Raman spectrometer.
- The BHIS can position the inspection tool from depths ranging from 0 to 25m.



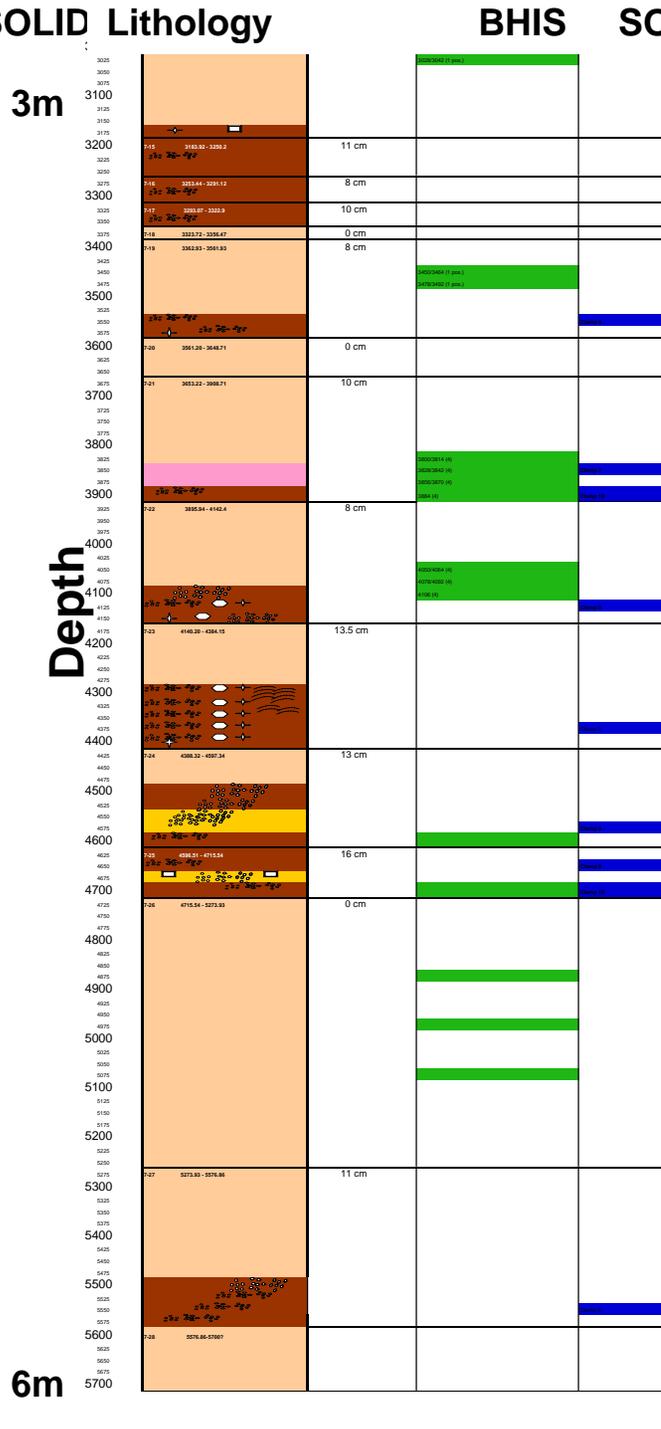
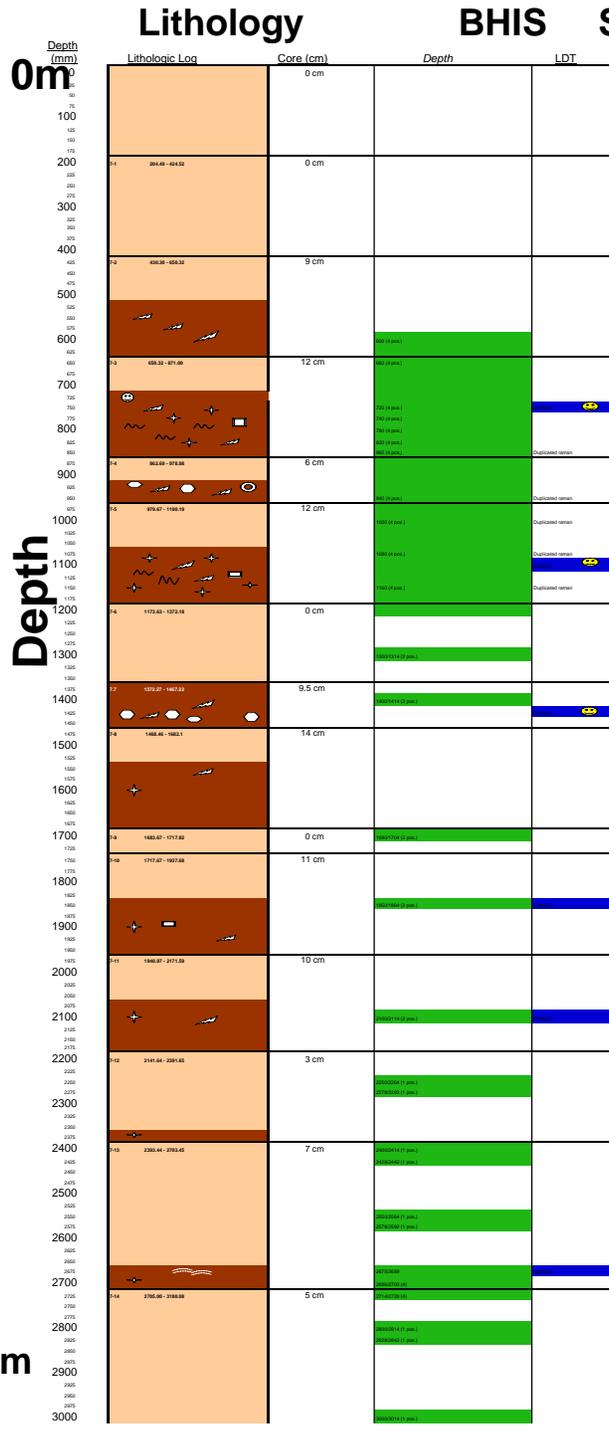
Mission Setup



Remote Science Mission

- Mission directed by remote science team for 1 month, Sept. 2005
- • Daily commands to field team, daily uploads of data obtained to Science data server





LEGEND	
	granular texture
	vugs
	quartz
	wish bones
	fractures
	rims
	pyrite casts
	bugs
	BHis AREA
	Botryoidal textures
	No core recovered
	gossan core*
	Felsic/Silicious
	Clay-rich clastic layer
	SOLID Sample

3m

6m

The Geologic Story

FORMATION

1. **Volcaniclastic host rock (permeable enough to allow hydrothermal fluids to flow)**
2. **Deposition of sulfide minerals via hydrothermal processes**
3. **Exposure to near surface environment allowed oxidation of original sulfide-rich material to form gossan**

Gossan

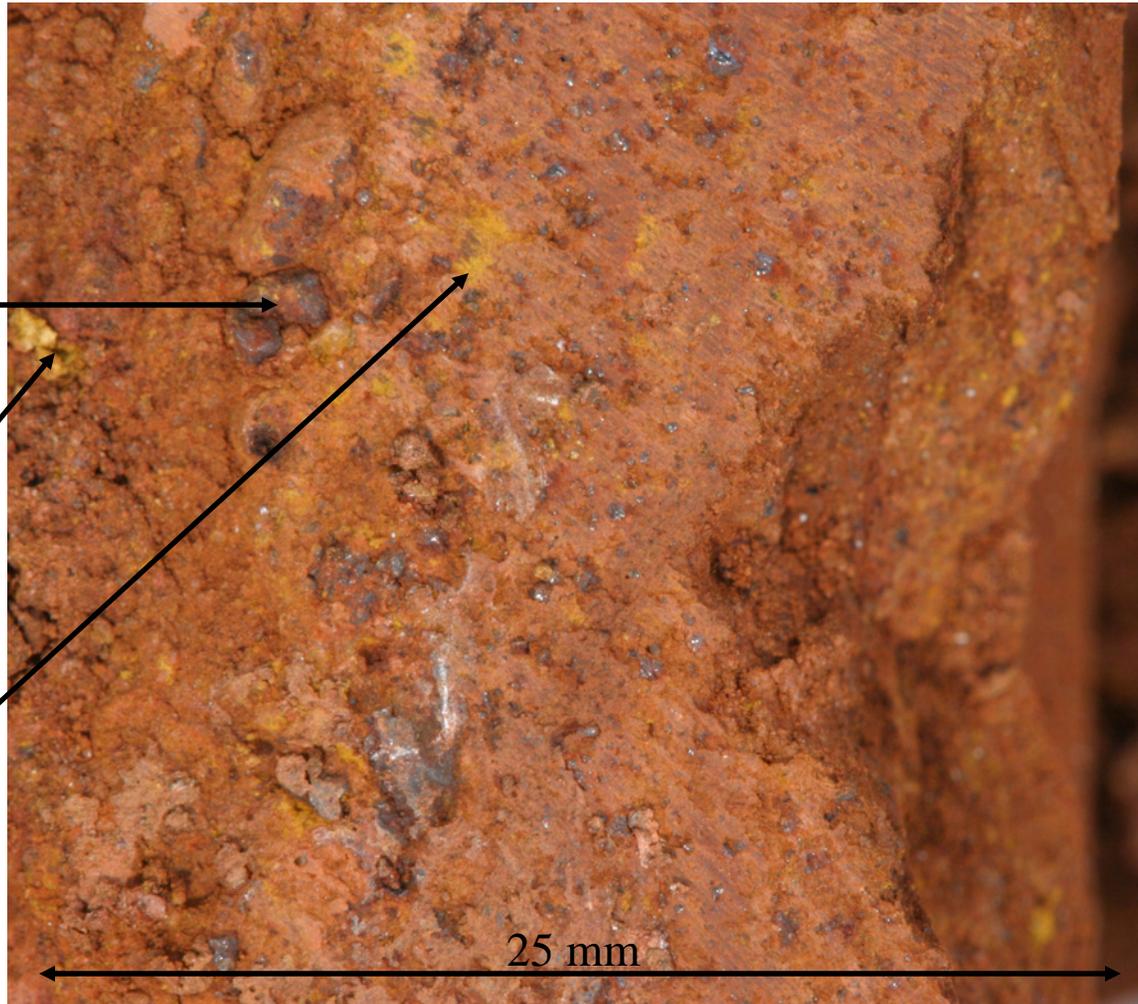
- **Oxidized, weathered, decomposed rock**
- **Oxidized sulfides and leaching out of sulfur and metals**
- **Remnant products = BOXWORKS (quartz lined cavities retaining shape of original crystals)**
- **Quartz and iron oxides (limonite, goethite, jarosite) are pseudomorphs replacing pyrite and primary ores**

The Geologic Evidence

Possible
mineralogy

Pyrite?
(FeS_2)

Jarosite?
($\text{KFe}_3(\text{OH})_6$
(SO_4)₂) or
Goethite?
(FeOOH)



Volcaniclastic
texture

Lithic or
pyrite clasts

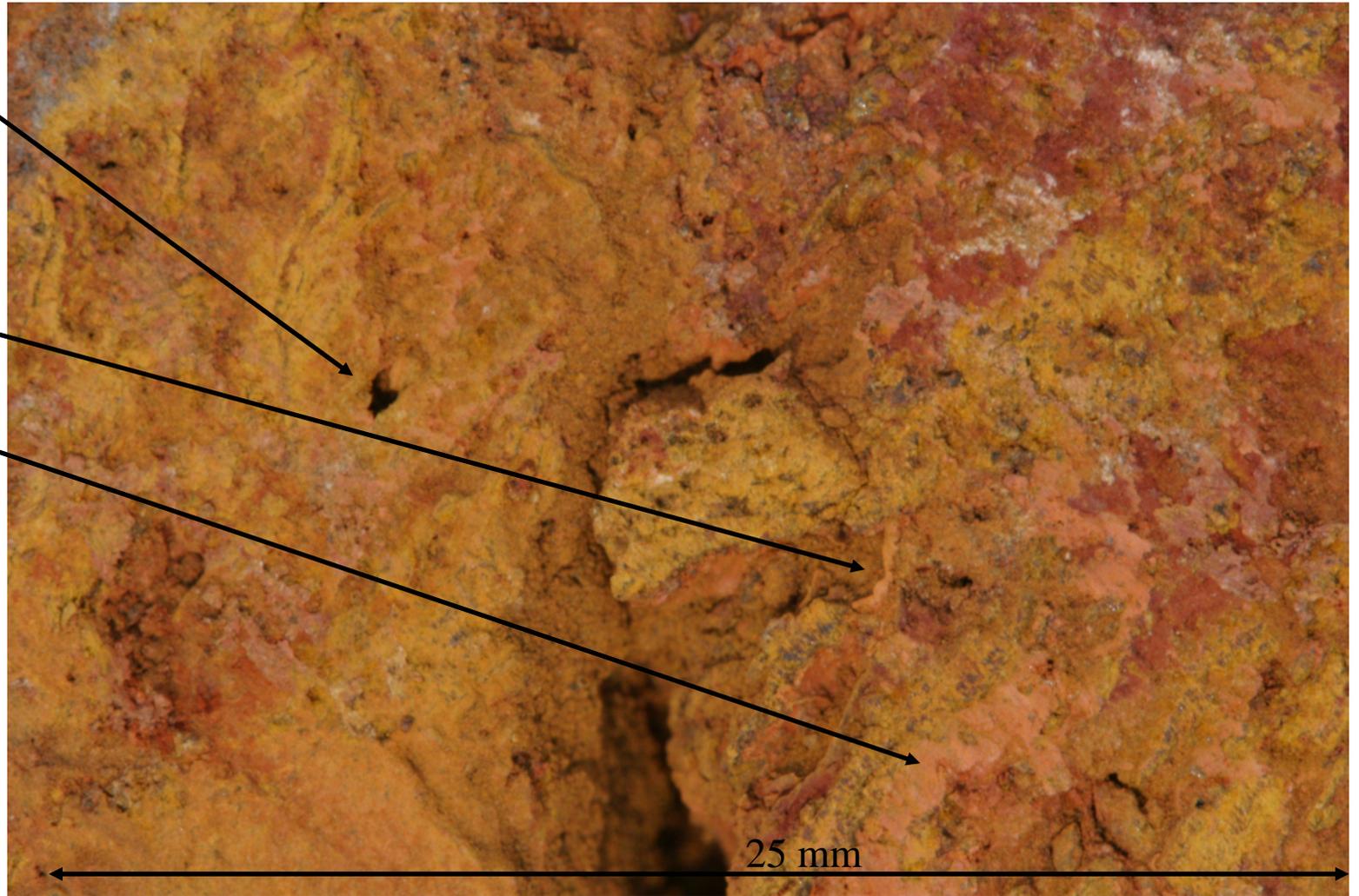
Core 21 (depth = 3908 mm)

The Geologic Evidence

Hollow vugs

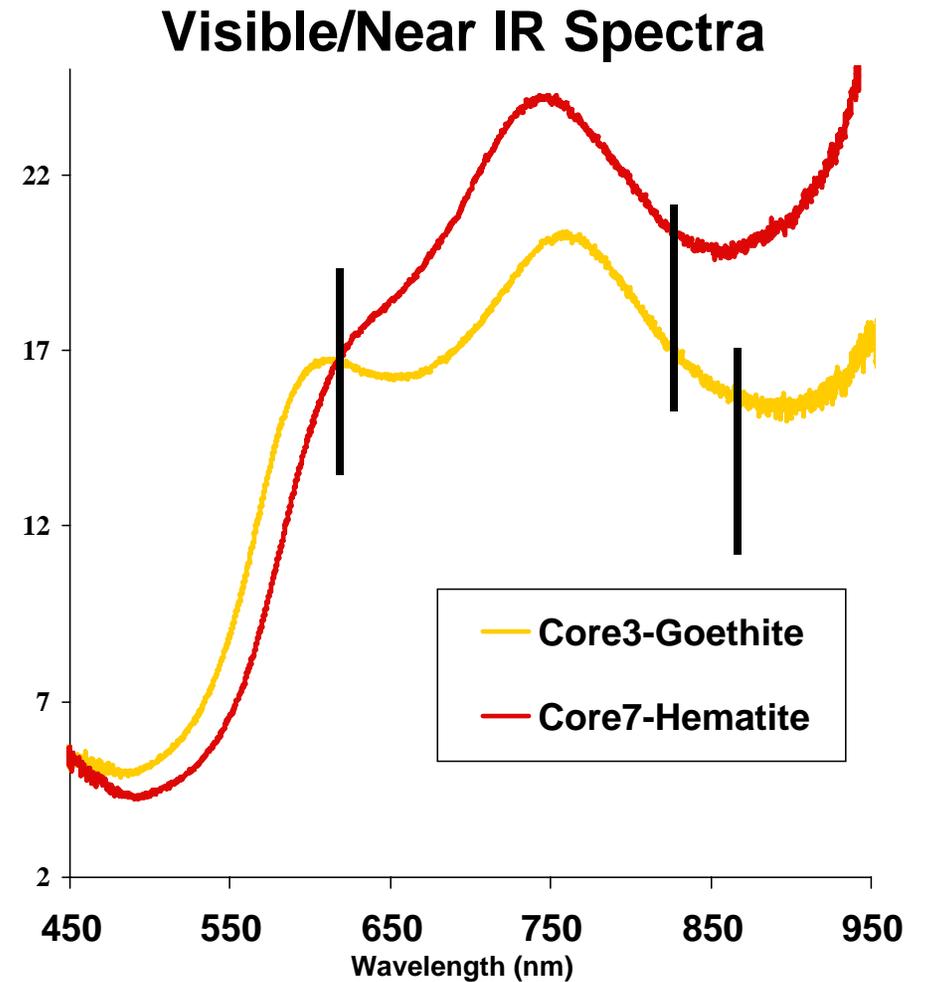
Veins of
material

Different
mineralogy in
deeper core
samples?
(yellow, pink
materials)

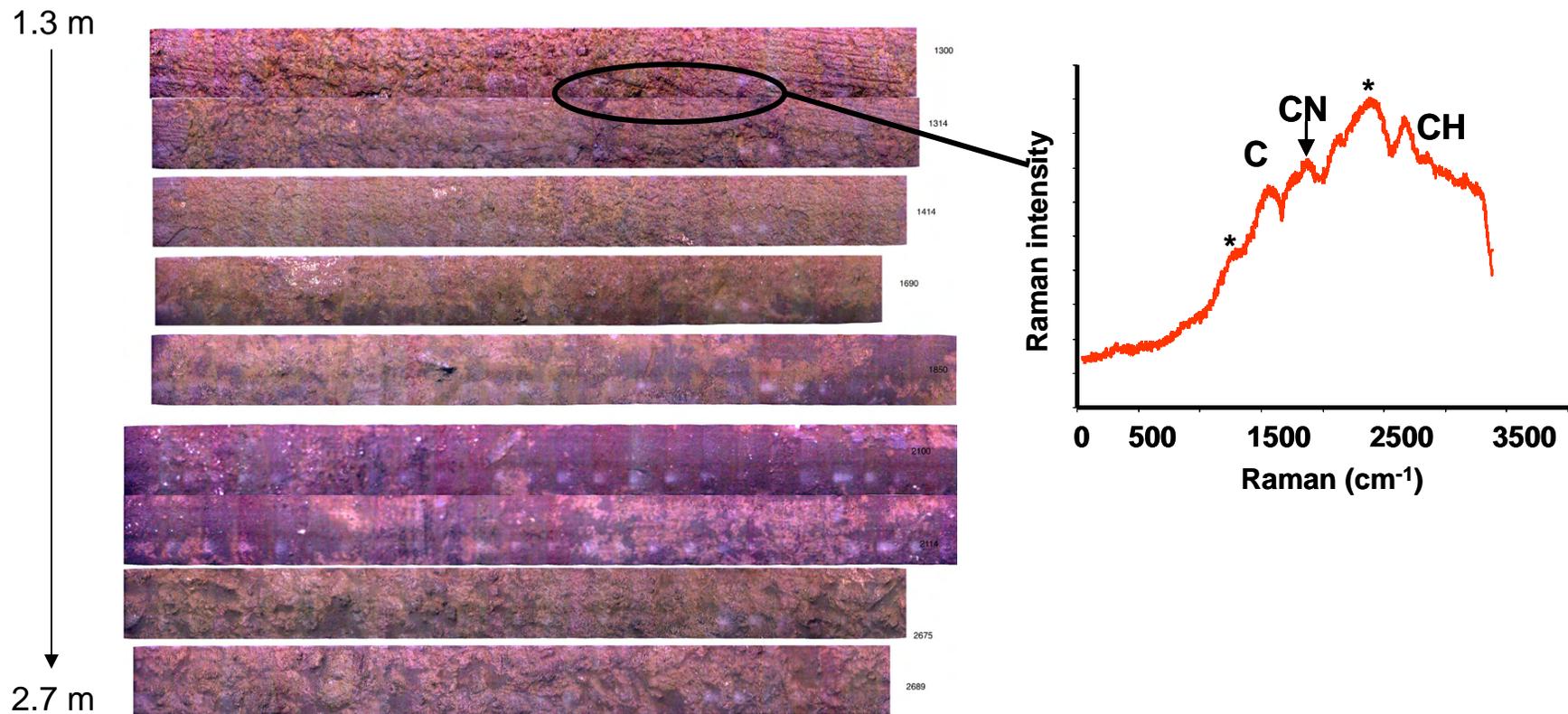


Core 23 (depth = 4384 mm)

Spectral Interpretation of Fe-Mineralogy



Raman spectral analysis reveals organic carbon at some locations in the hole



Organics are detected in all good quality Raman spectra

Signs Of Life Detection (SOLiD)

Biological Indicators found

DEPTH

Core 3:

0.8m

- *Leptospirillum ferrooxidans*
- cAMP
- Cortisol

Core 5:

1.2m

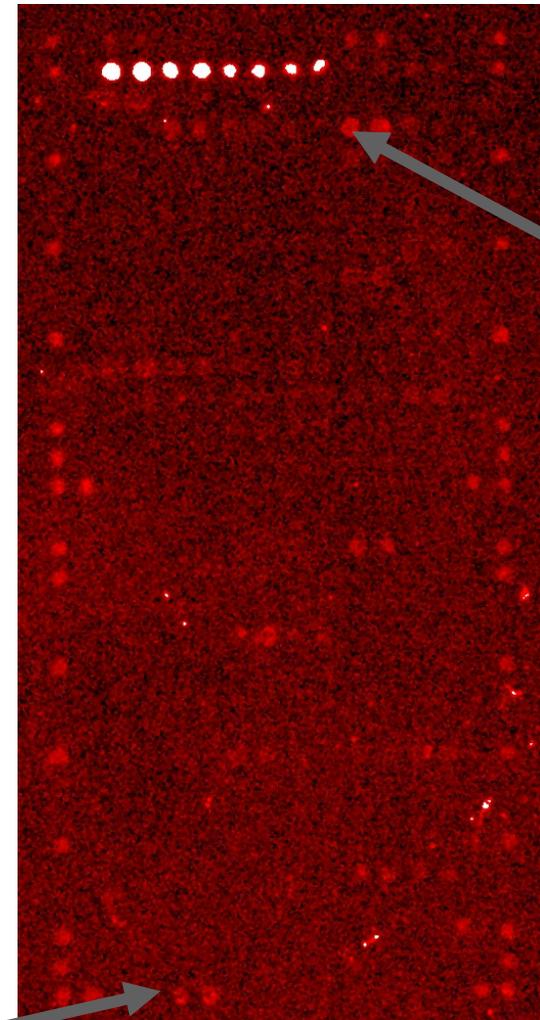
- *Leptospirillum ferriphilum*
- Gram Positive Bacteria

Core 7:

1.4m

- *Shewanella gelidimarina*
- *Shewanella oneidensis*
- *Leptospirillum ferriphilum*
- *Acidophilum albertensis*
- Gram Positive Bacteria
- *Cryobacterium psychophilum*

Leptospirillum ferrooxidans



cAMP

CORE 3

Key Results

- Autonomous drilling and sample handling to 6 m depth in 30 days of operation.
- Drilling to search for life successfully identified *in situ* organisms (and different populations at different depths). First demonstration of this in a fully robotic field experiment. 18 samples analyzed for life signatures. “Positive” signatures detected in 5 of these.
- Core recovery was 30% overall. Down hole imaging compensated for poor core recovery by filling in the holes.
- Science team correctly identified nature of deposit and mineralogy using instrumentation provided. Each instrument system provided important information about the geology and biology.
 - Context and microscopic imaging key for identification of lithology and clues to mineralogy
 - Spectroscopy and hyperspectral key imaging for mineral identification
 - Down hole Raman spectrometer identified organics.